

GLASS MEMORIES®



CORNING
ELECTRONICS
A DIVISION OF CORNING GLASS WORKS

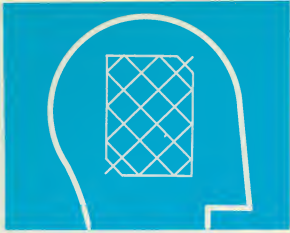


TABLE OF CONTENTS

1. Introduction
2. Applications
3. Advantages
4. History
5. Comparison with other storage methods
6. Electrical description
7. Physical description
8. Technical discussion
 - 8.1 Storage capacity
 - 8.2 Delay time
 - 8.2.1 Tolerance
 - 8.2.2 Stability
 - 8.3 Bit frequency/Data rate
 - 8.4 Attenuation and insertion loss
 - 8.4.1 Delay medium loss
 - 8.4.2 Beam spreading loss
 - 8.4.3 Off resonance loss
 - 8.4.4 Conversion efficiency loss
 - 8.4.4.1 Quartz transducer
 - 8.4.4.2 Ceramic transducer
 - 8.5 Signal to noise ratio
 - 8.6 Environmental stability
9. Catalog
 - 9.1 Standard bit rate series
 - 9.2 Finished designs

1 INTRODUCTION

Solid ultrasonic delay lines for all applications have been principally supplied by Corning since 1952.

CORNING Glass Memories, high speed delay lines for digital storage, are fully described in this catalog. Supplements will cover other, non-digital delay lines in greater detail.

Non-digital delay lines include delay lines for CW and pulsed CW operation at frequencies from 1 to 60 mc and delay times from 1 to 5000 μ secs. These delay lines have found application in radar return signal MTI and integrator circuits, as periodic and coherent memory filters, and in other analog storage applications.

Corning also manufactures complete systems (or provides the delay line by itself) which yield tapped and variable delays using the photoelastic principle. These delay lines and systems have found use in wide band secure communications, auto- and cross-correlation techniques, and pulse compression radar systems.

2 APPLICATIONS

Shift registers

Input-output buffers

Display buffers

Scratch-pad memories in general-purpose computers

Main memories for:

Small special-purpose computers used in military fire and tracking control

Small process control computers

Communications buffers or processors
DDA's

High speed associative memories

High speed DELTIC memories

Stable time reference-trigger sources

3 GLASS MEMORY ADVANTAGES

- High frequency serial capability . . . excellent video response and time stability (4.) (8.2.2)
- Advantageous cost-performance trade-off between cores and drums (5.)

- Economy . . . durability . . . outstanding performance in adverse environments (7.) (8.6)
- High data rates (8.3)
- Low signal loss (8.4)

4 HISTORY

Ultrasonic delay lines were first used for storage purposes in the EDSAC, SEAC, RAYDAC, and UNIVAC I computers. The delay medium used in these early delay lines was mercury, and the bits consisted of RF bursts at 10 to 30 mc. The transducers were crystalline quartz.

These delay lines had several disadvantages: poor reliability caused by leakage of the mercury from its cylinder, a pronounced time-delay variation with temperature, and a need for complicated driving and detection circuitry. Mercury delay lines were abandoned as computer storage media with the development of drum and core memories.

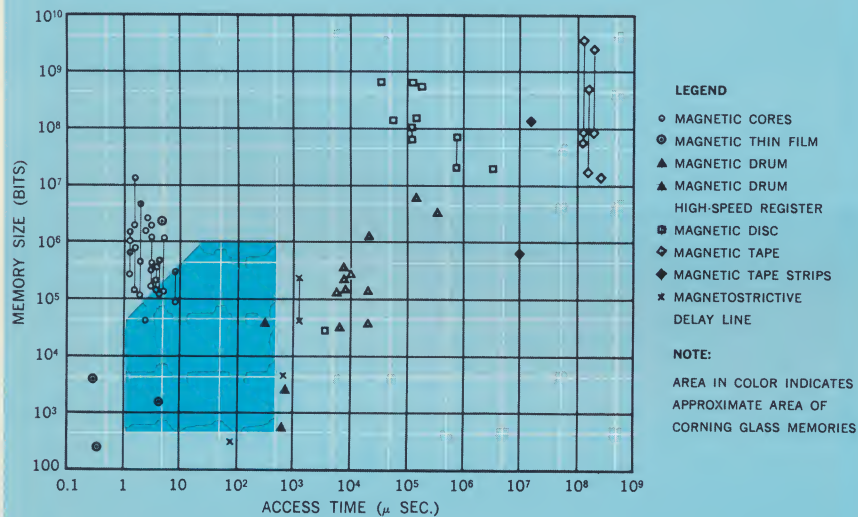
Shortly thereafter, the development of the magnetostrictive delay line once again interested computer designers in delay lines for digital storage. These delay lines are designed to operate with short video pulses, eliminating the need for an RF carrier. The delay medium is a metal wire which can be made almost time-invariant with temperature, besides being solid, which means better reliability.

CORNING Glass Memories represent a third generation of delay lines for digital storage, combining the high frequency capability of the mercury delay line with the video response and time stability of the magnetostrictive delay line.

These devices are made with a time-invariant glass and piezoelectric transducer. Their operating frequency range starts where that of magnetostrictive delay lines leave off (1-2 mb/s), and their solid block delay medium configuration is better suited for operation in severe mechanical environments than either liquids or wires.

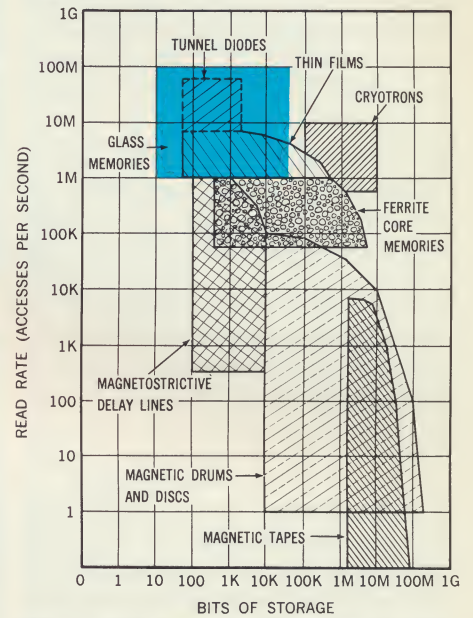
Device	Permanence	Type of Access	Access Time, Average	Bits/Element	Capacity (Bits)	Cost/Bit with Access Circuits
Tunnel Diodes	Volatile	Random	20 ns to 1 μ sec	1	to 1×10^5	\$0.50 to \$2.00
Cryogenic	Volatile	Random	100 ns to 2 μ sec	to 1×10^5	to 1×10^6	\$0.20 to \$1.00
Thin Films	Nonvolatile	Random	200 ns to 5 μ sec	to 10^4	300 to 3×10^4	\$0.20 to \$3.00
Ferrite Cores	Nonvolatile	Random	0.5 to 10 μ sec	1	5×10^4 to 1×10^7	\$0.15 to \$1.00
Delay Lines	Volatile	Cyclic				
Glass Memories			5 to 500 μ sec	to 5×10^4	to 5×10^6	\$0.02 to \$0.50
Magnetostrictive Strip			100 to 5×10^3 μ sec 100 to 5×10^3 μ sec	to 7×10^3 to 5×10^3	to 5×10^5 to 5×10^5	\$0.05 to \$0.20 \$0.05 to \$0.20
Magnetic Drums Working (operating) Storage	Nonvolatile	Cyclic	5×10^2 to 5×10^4 μ sec	to 10^5	500 to 5×10^5	\$0.10 to \$0.30
Backup Storage			1×10^4 to 5×10^5	to 10^7	1×10^5 to 1×10^7	\$0.02 to \$0.15
Magnetic Discs	Nonvolatile	Cyclic	5×10^3 (Bernoulli) to 1×10^6 μ sec	to 1×10^6	5×10^4 (Bernoulli) to 1×10^9	\$0.001 to \$0.05

Figure 1 CAPACITY vs SPEED



After S. W. Miller: "Fundamental Investigation of Digital Computer Storage and Access Techniques," AF 30(602)-2227, 5/61.

Figure 2 CAPACITY VS DATA RATE



After W. W. Carver: "Comparing Storage Methods," "Electronics Industries," 8/62.

5 COMPARISON WITH OTHER STORAGE METHODS

Compared with other storage methods, Glass Memories can be described most simply as providing an advantageous cost-performance trade-off between cores and drums. Glass Memories, at between 2¢ and 50¢/bit, are 5 to 10 times less expensive than cores and only slightly more expensive than drums. However, Glass Memories have average access times of 1 μ sec to 500 μ sec, 2 to 25 times greater than cores, but 10 to 100 times shorter than drums. Finally, Glass Memories can operate at rates up to 100 mb/s, 10 times faster than cores and 1000 times faster than drums. Table I and Figures 1 and 2 demonstrate these trade-offs more clearly.

6 ELECTRICAL DESCRIPTION

CORNING Glass Memories can store up to 4000 bits with RZ coding (7000 bits with NRZ) in temperature-invariant glass, and up to 25,000 bits RZ (40,000 bits NRZ) in low-loss fused silica. Bit rates vary from



1 to 50 mb/s RZ, at average access times of 0.5 μ sec to 500 μ sec (delay times of 1.0 μ sec to 1000 μ sec). Glass Memories are completely linear voltage devices. Input signal to output signal insertion loss ranges from 30 db to 80 db, and output signal to noise ratio ranges from 3:1 to 20:1.

7 PHYSICAL DESCRIPTION

Digital Glass Memories usually take one of two forms—a flat plate of glass packaged in a metallic or epoxy case, or a rod of glass equipped with mounting brackets and coated for protection.

Rod-type delay lines are limited in time delay, because the velocity of sound in zero t/c glass is approximately 0.1 inch per 1 μ sec. Any delay line above 100 μ sec is thus inconveniently long. However, because of their much simpler construction, rod-type delay lines can be made very economically.

In general, the flat plate of glass is used above 100 μ sec. In this configuration, temperature-invariant delay lines up to 400 μ sec are packaged in cases approximately six inches by eight inches, or smaller, by 0.75 inch thick. Fused silica delay lines are usually much larger due to the greater bit storage and the possible requirement for temperature control.

By virtue of their simple, monolithic construction, solid ultrasonic delay lines are both economical and rugged. The convenient epoxy case permits quick design to fit almost any size and shape requirement, and cushions and seals the Glass Memory against all extremes of environment.

8 TECHNICAL DISCUSSION OF GLASS MEMORIES

8.1 STORAGE CAPACITY

The storage capacity of a Glass Memory is the product of the delay time and the bit rate. In Figure 3 it is plotted against average access time.

8.2 DELAY TIME

The delay time of a Glass Memory is equal to the total path or length of the beam, divided by the velocity of sound in the delay line blank. Table II and Figure 4 illustrate this fact.

Table II
VELOCITIES OF DELAY LINE GLASSES

$v = 0.0985''/\mu\text{sec}$ for Code 8875 zero t/c glass
$v = 0.1110''/\mu\text{sec}$ for Code 8877 zero t/c glass
$v = 0.1482''/\mu\text{sec}$ for Code 7940 fused silica

Delay time of Glass Memories ranges from 1 μ sec to 400 μ sec in Code 8875 and Code 8877 glasses, equal to a path length of up to four feet, and from 350 μ sec to 1000 μ sec in Code 7940 fused silica, equal to a path length of up to 13 feet. By reflecting the ultrasonic beam inside a glass plate, the piece of glass required to provide these path lengths can be made relatively small. Practical maximum package sizes are 6" x 8" x 1" for Code 8875 and Code 8877 glass, and 12" x 15" x 2" for Code 7940 fused silica.

Figure 3

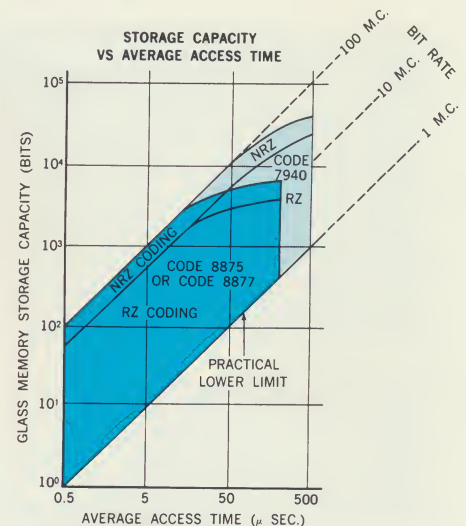
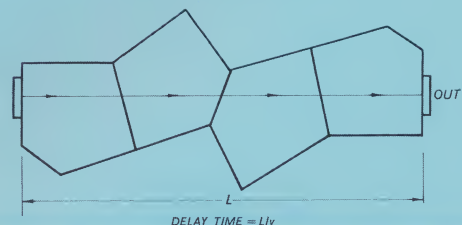
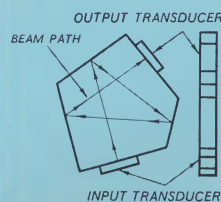


Figure 4 TYPICAL GLASS MEMORIES



8.2.1 DELAY-TIME TOLERANCE

Below is a table illustrating the grinding tolerance required to achieve a given delay-time tolerance on fused silica and zero t/c blanks of various reflection schemes.

Table III
GRINDING TOLERANCE VS. DELAY-TIME TOLERANCE
Grinding Tolerance Each Facet (mils) (disregarding tolerance on transducer facets)

Delay-Time Tolerance (nsec)	Fused Silica No. of Reflections				Zero T/C Glass (8875) No. of Reflections			
	1	5	10	20	1	5	10	20
±1	±.075	±.014	±.0075	±.0037	±.05	±.01	±.005	±.0025
±5	±.37	±.075	±.037	±.0185	±.25	±.05	±.025	±.0125
±10	±.75	±.14	±.075	±.037	±.5	±.1	±.05	±.025
±20	±1.5	±.295	±.15	±.075	±1.0	±.2	±.10	±.05
±30	±2.2	±.445	±.22	±.11	±1.5	±.3	±.15	±.075
±50	±3.7	±.75	±.37	±.185	±2.5	±.5	±.25	±.125
±100	±7.5	±1.4	±.75	±.37	±5.0	±1.0	±.5	±.25

In addition to grinding tolerances, delay-time tolerance is affected by velocity variation in the zero t/c glasses. Velocity variation in fused silica is also present but to a lesser degree.

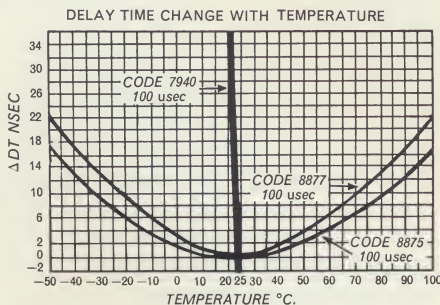
8.2.2 DELAY-TIME STABILITY

The coefficients important to the delay-time stability of Glass Memories are listed in Table IV

Table IV DELAY-TIME STABILITY COEFFICIENTS			
	Code 8875	Code 8877	Code 7940
Temperature Coefficient of Time Delay (TC)	$0 \pm 1.0 \text{ ppm}/^\circ\text{C}$ at 25°C	$0 \pm 1.0 \text{ ppm}/^\circ\text{C}$ at 25°C	$-81.5 \pm 1.5 \text{ ppm}/^\circ\text{C}$
Variation of Temperature Coefficient of Time Delay with Temperature $\left\{ \frac{d(TC)}{dT} \right\}$	$+ .06 \text{ ppm}/^\circ\text{C}^2$	$+ .09 \text{ ppm}/^\circ\text{C}^2$	$+ .07 \text{ ppm}/^\circ\text{C}^2$ approximately
Delay Time Aging	-1 part in 240,000 from shipment	-1 part in 100,000 from shipment	

Plots of the variation of time delay for a 100 μsec Glass Memory made from Code 8875 and Code 8877 glass are given below. A plot for a Glass Memory made from Code 7940 fused silica is shown for comparison.

Figure 5



The equation commonly used to calculate ΔDT versus ΔT is

$$(1.) \Delta DT = DT_0 \times (T_1 - T_2) \times \left\{ \frac{TC_1 + TC_2}{2} \right\}$$

Where:

ΔDT = change in delay time

DT_0 = nominal delay time

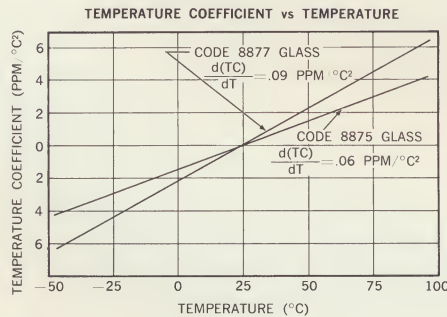
T_1 & T_2 = temperatures at the extremes of the interval

TC_1 & TC_2 = the temperature coefficients at T_1 and T_2 respectively (See Figure 6)

If ΔDT versus ΔT was not a parabola, it would be best to obtain values for TC_1

and TC_2 from a plot of temperature coefficient versus temperature, as in Figure 6, and substitute in equation (1).

Figure 6



However, ΔDT can also be expressed by the equation

$$(2.) \Delta DT = DT_0 \times (T - T_0)^2 \times \frac{1}{2} \frac{d(TC)}{dT}$$

which depends only on the slope of the plots in Figure 6. This slope is a constant for a parabola.

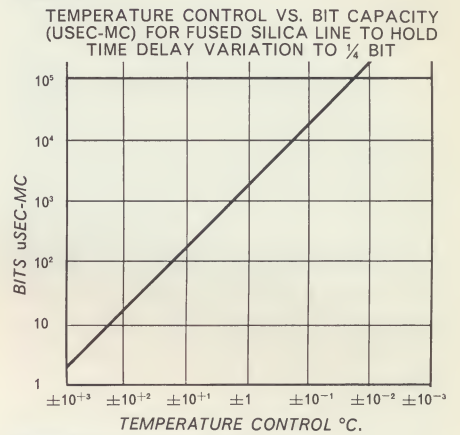
The corresponding values for the three glasses are given in Table IV. Different melts of Code 8877 glass have been melted with T_0 occurring at roughly 0°C , 30°C , 60°C .

The slope $\left\{ \frac{d(TC)}{dT} \right\}$ of the different melts remains the same.

The graph (Fig.7) shows the temperature control required to hold a fused

silica Glass Memory to within $\pm 1/4$ of a bit at various delay times and frequencies.

Figure 7



8.3 BIT FREQUENCY OR DATA RATE

The maximum bit or data rate for a Glass Memory is generally defined in the RZ mode, because an ultrasonic delay line responds only to changes in voltage level. Glass Memories can be used in NRZ systems at up to twice the maximum RZ bit rate if the proper conversion circuits are employed at the output.

Generally, the maximum data rate is considered to be equal to the peak frequency of the delay line. The peak frequency of the delay line is the frequency at which the attenuation in the delay line is minimum. This peak is determined by the frequency response characteristic of the transducer pair and the medium loss variation with frequency. Since the delay medium loss increases with frequency, the peak frequency of a delay line is below the resonant frequency of the transducer pair.

Most of the signal loss in the medium is due to absorption of the signal by the glass. A smaller amount of the loss is due to spreading of the acoustic beam. The loss constants for absorption in the glass are given below:

Table V ACOUSTIC LOSS CONSTANTS DELAY LINE GLASSES	
Code 8875	$6.0 \times 10^{-3} \text{ db}/\mu\text{sec-mc}$
Code 8877	$4.0 \times 10^{-3} \text{ db}/\mu\text{sec-mc}$
Code 7940	$0.15 \times 10^{-3} \text{ db}/\mu\text{sec-mc}$

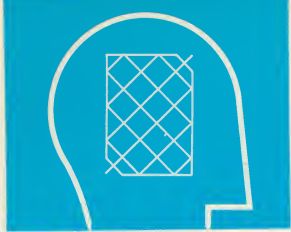
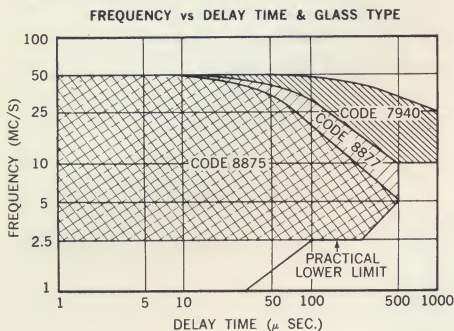


Figure 8



The loss constant for fused silica is so low that it rarely is the limiting factor in the maximum capacity of a digital line. The maximum frequency as a function of delay time for the two zero t/c glasses is given in the graph below.

8.4 ATTENUATION AND INSERTION LOSS

Attenuation in delay lines is the sum of four variables:

1. attenuation of the acoustic signal by hysteresis loss in the delay medium,
2. spreading of the acoustic beam as it travels through the delay medium,
3. operation of the delay line at a frequency other than the transducer peak frequency,
4. conversion efficiency of the two transducers.

8.4.1 DELAY-MEDIUM LOSS

Losses due to absorption by the delay medium can be calculated from the loss constants given in Table V and the following equation:

Loss (db) = $\alpha \times f \times DT$ where α = acoustic loss constant, f = frequency of operation, and DT = delay time. This loss varies with temperature as shown in Table VI.

Table VI VARIATION OF GLASS LOSS WITH TEMPERATURE	
Code 8875	-.3%/°C approx.
Code 8877	-.3%/°C approx.
Code 7940	-5 to -10%/°C

8.4.2 BEAM SPREADING LOSS

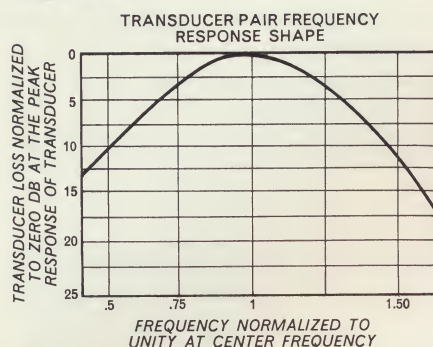
The loss due to the spreading of the acoustic beam is difficult to calculate,

since it is a complex function of the length of the line, the length of the transducer, and the peak frequency of the delay line. However, generally this loss will be less than 6 db. For lines operated above 10 mc the loss amounts to only one or two db.

8.4.3 OFF RESONANCE LOSS

The shape of the frequency response of a transducer pair is shown below:

Figure 9

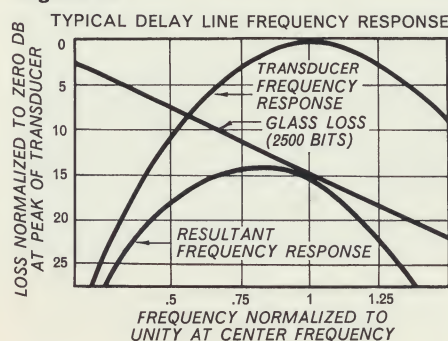


It is obvious that the increasing loss with frequency due to signal loss in the glass (acting like an RC filter) will have the effect of bringing the peak response of the line below the resonant frequency of the transducer pair.

The loss due to operation off the resonant frequency of the transducer pair can be found directly from the Figure 9 graph if the ratio of the peak frequency to the transducer resonant frequency is known.

A line will peak at the frequency at which the glass loss slope is equal and opposite to the transducer response slope, as illustrated in Figure 10.

Figure 10



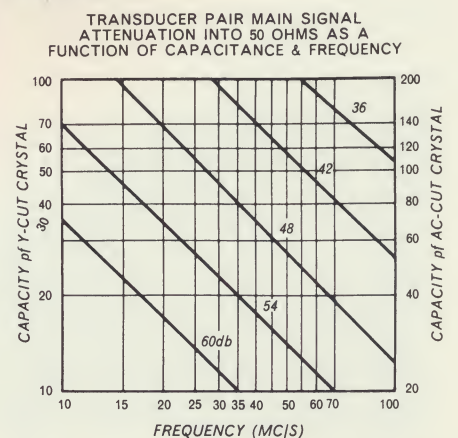
8.4.4 CONVERSION EFFICIENCY LOSS

The conversion efficiency of the transducer is very dependent upon how it is matched to the external electrical driving and load impedances. It is also dependent upon which of the two available transducer materials are used.

8.4.4.1 QUARTZ TRANSDUCERS

Figure 11 shows the digital attenuation of a quartz crystal transducer pair as a function of end cell capacitance, transducer frequency, and crystal cut.

Figure 11



The main signal attenuation of a quartz transducer Glass Memory operating into a 50 ohm resistive load is fairly easily calculated from the preceding graphs and formulas. This is based on a known equivalent circuit for quartz transducers. In simplified form, the equivalent circuit of a delay line with matched input and output transducers is shown in Figure 12.

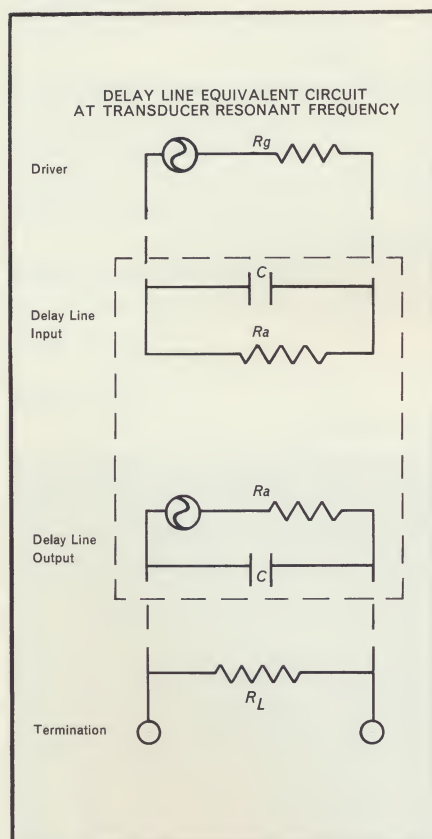
Typical values might be

	Quartz transducer	Ceramic transducers
C	= 65 ± 5 pf	500 pf
Ra	= 10K ohms	100 r
Rg = RL	= 50 ohms	50 r
Frequency	= 20 mc/s	5 mc

At the output the quartz transducer delay line looks like a constant current generator, so increasing R_L increases the

voltage output of the line until $X_C \leq R_L$. The attenuation of a digital delay line with a quartz transducer at the output can thus be reduced by operating it into a higher resistance than the standard 50 ohms. However, this gain is offset by a loss of electrical bandwidth and an increase in the RC time constant. An optimum R_L exists for each particular delay line and pulse requirement.

Figure 12



8.4.4.2 CERAMIC TRANSDUCERS

The attenuation in delay lines using ceramic transducers is much less than in those using quartz transducers. The ceramic transducer differs from the quartz transducer in coupling coefficient and dielectric constant. A comparison is shown in the table below for lead zirconate-titanate transducers operating in the thickness shear mode.

Table VII DELAY LINE TRANSDUCER MATERIAL CHARACTERISTICS		
Material	Coupling Coefficient	Dielectric Constant
Ceramic	.66	870
Quartz, Y cut	.142	4.58

Since the efficiency of a transducer varies with the square of the coupling coefficient and directly with the dielectric constant, the ceramic transducer is vastly more efficient than the quartz transducer. However, the large dielectric constant of the ceramic yields a transducer with an extremely high capacitance. In addition, the terminal resistance R_a , being a measure of the conversion of electrical to acoustical energy, will be several orders of magnitude lower than that of comparable quartz transducers. Typical values for a 5 mc transducer are:

$$C = 500 \mu f$$

$$R_a = 100 \text{ ohms}$$

If the size of the transducer required is known, the following formulas can be used to calculate C and R_a where A is the area in square inches and f is the transducer resonant frequency in megacycles. However, proper engineering design can produce more desirable values of C and R, as in the example listed above.

Table VIII CERAMIC TRANSDUCER CONSTANTS	
$C = 2000 (Af) \mu f$	
$R_a = 60 \text{ to } 150 / Af^2 \text{ ohms}$	

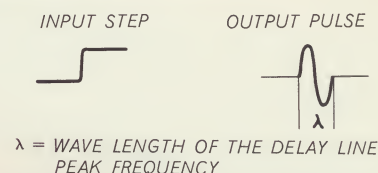
The attenuation produced by a ceramic transducer delay line results from a combination of the same factors as that of the quartz line—transducer, glass, beam spreading, and off-transducer resonance operation. If a transducer pair is properly terminated, its contribution to the loss of the line will be 15 to 30 db for practical delay lines regardless of the size or frequency of the transducer. For calculation of the loss due to operation off crystal resonance, the curve for the quartz transducer can be used to a good

approximation. Actually, the bandwidth runs between 50% and 65% of the center frequency, and the curve is flatter in the center than for the quartz transducer case.

8.5 SIGNAL-TO-NOISE RATIO

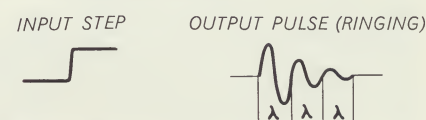
The response of a delay line to a voltage step is a function of (1) how well the acoustic impedances of the transducer materials and delay medium match each other, (2) how well the electrical impedances of the input and output transducers match the driving and detection circuits, and (3) how well phase and amplitude are preserved in the acoustic pulse.

In general, a good digital delay line will have a step response with the negative and positive areas of the pulse approximately equal as below.

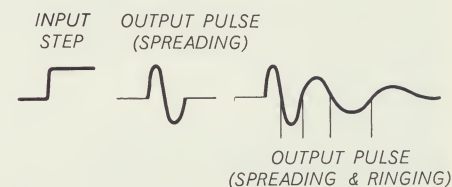


Being a completely linear device, the response to a pulse is a summation of step responses.

Output pulse distortion can occur if transducer or delay line materials are improperly chosen. "Ringing," such as is shown, then occurs.



Propagation which produces phase or amplitude distortion will also cause "spreading" or "spreading and ringing" in the output pulse.



Because of their higher acoustic attenuation constants, "spreading" of the output pulse quite often cannot be avoid-



ed in temperature-invariant glass delay lines, and results in the ability to use the Glass Memory with NRZ coding only 50% to 75% faster than with RZ coding. "Ringing" is easily controlled, being at least 20 db below the main pulse on most Glass Memories.

Other sources of noise in the Glass Memory arise from its propagation characteristics. The resulting individual spurious pulses are always 20 db to 40 db below the main output signal and, under pattern conditions, combine with distortions in the output pulse to produce dynamic signal to noise ratios of 3:1 to 20:1.

8.6 ENVIRONMENTAL STABILITY

Besides the stability with temperature shown in Figure 2 and 3, special Corning Glass Memories have been designed to meet the following environmental specifications:

A. Operating

1. Impact Shock 85g, 100 ms
2. Vibration 50g RMS, 60-2000 cps

3. Pressure 0.3 μ @ 100°C for 96 hours
4. Moisture Resistance & Humidity Per MIL-STD-202, Method 106
5. Temperature -55°C to +85°C
6. Radiation
 - a. Neutron 10^{16} N/Cm², 0.3 MEV
 - b. Gamma 10^{10} ergs/g-(C)
7. Storage 625 hours at +100°C
8. Thermal Shock -55°C to +85°C

9 CATALOG

The following pages contain catalog sheets on the standard series of Glass Memories. More sheets will be added as new Glass Memories are developed.

The nomenclature for describing CORNING Glass Memories follows:

- A. Code Number. The code number completely identifies a Glass Memory. Two lines with the same code number must be identical in all respects.
- B. Descriptive Nomenclature. Each Glass Memory has a descriptive

nomenclature which describes its general characteristics. This is illustrated by the following example: CQS-10-100-3H

C—Input Transducer Material—Ceramic
 Q—Output Transducer Material—Quartz
 S—Delay Medium—Fused Silica (Z—zero t/c glass)
 10—Frequency—10 mc* RZ
 100—Delay Time—100 μ sec
 3—Glass Memories per package
 H—Thermal Characteristic—Heated**

*Frequency is in megabits/sec. This represents the maximum recommended data rate. By special pulse-detection techniques, the delay line can be operated up to 33% faster.

**Thermal characteristics are either H for heated or nothing for unheated.

Special characteristics include

F—folded
 O—optical



9.1 CORNING GLASS MEMORIES

Standard Bit Rate Series Representative Specifications

Type CZ-2.5 LOW CAPACITANCE

This Glass Memory is designed for minimum drive power at low bit rates.

Delay Range.....	12 μ sec to 200 μ sec
Maximum recommended RZ Bit Rate...	1 mb/s
Nominal Pulse Width.....	200 ns
Voltage Attenuation.....	28 to 40 db
Nominal Load Impedance.....	1 kil ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	3:1 to 10:1 at 1 mb/s
Input Terminal Resistance.....	1270 ohm $\pm 10\%$ at 2.5 mc/s
Output Terminal Resistance.....	140 ohms $\pm 10\%$ at 2.5 mc/s
Input Terminal Capacitance.....	115 pf $\pm 10\%$ at 2.5 mc/s
Output Terminal Capacitance.....	1100 pf $\pm 10\%$ at 2.5 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" x 2" x $\frac{1}{2}$ " to 3" x 6" x $\frac{5}{8}$ "



INPUT PULSES



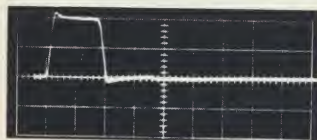
OUTPUT PULSES

SWEEP RATE 200 NS/CM

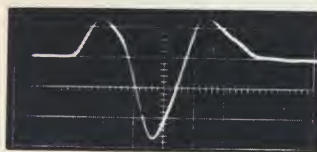
Type CZ-2.5 HIGH CAPACITANCE

This delay line is designed for maximum signal-to-noise ratio at bit rates up to 2.5 mc.

Delay Range.....	12 μ sec to 200 μ sec
Maximum recommended RZ Bit Rate...	2.5 mb/s
Nominal Pulse Width.....	200 ns
Voltage Attenuation.....	28 to 40 db
Nominal Load Impedance.....	50 ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	4:1 to 10:1, at up to 2.5 mb/s
Input Terminal Resistance.....	400 ohm min. at 2.5 mc/s
Output Terminal Resistance.....	160 ohm $\pm 20\%$ at 2.5 mc/s
Input Terminal Capacitance.....	250 pf max. at 2.5 mc/s
Output Terminal Capacitance.....	2400 pf $\pm 10\%$ at 2.5 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" to 2" x $\frac{1}{2}$ " to 3" x 6" x $\frac{5}{8}$ "



INPUT PULSE



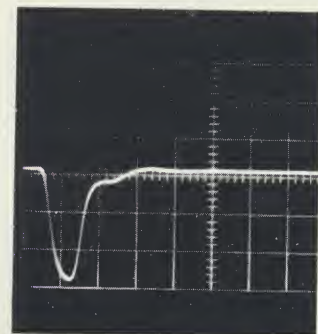
OUTPUT PULSE

SWEEP RATE 100 NS/CM

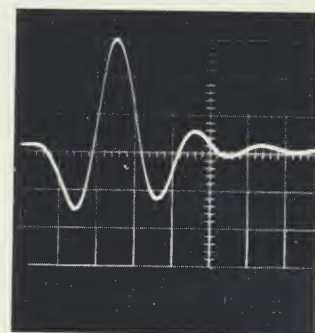
Type CZ-2.5 LOW ATTENUATION

This delay line is designed for use as a very stable fixed delay or trigger source. Attenuation has been minimized with some degradation in output pulse shape. This presents no difficulty with the low PRF of normal operation.

Delay Range.....	5 μ sec to 200 μ sec
Maximum PRF.....	1 kc/s to 100 kc/s
Nominal Pulse Width.....	200 ns
Voltage Attenuation.....	10 db to 20 db
Nominal Recommended Load Impedance.....	1K ohm min.
Nominal Recommended Driving Impedance.....	50 ohms nominal
Worst Spurious Signal	20 db below main output pulse
Input Terminal Resistance.....	140 ohms nominal at 2.5mc/s
Output Terminal Resistance.....	1300 ohms nominal at 2.5 mc/s
Input Terminal Capacitance.....	1100 pf nominal at 2.5 mc/s
Output Terminal Capacitance.....	150 pf max. at 2.5 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" x 1" x $\frac{1}{2}$ " to 3" x 6" x $\frac{5}{8}$ "



INPUT PULSE



OUTPUT PULSE

SWEEP RATE 200 NS/CM

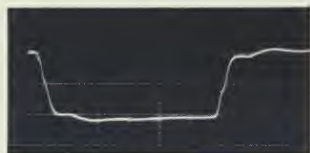
9.1 CORNING GLASS MEMORIES
Standard Bit Rate Series Representative Specifications

Type CZ-5

Delay Range.....	12 μ sec to 400 μ sec
Maximum recommended RZ Bit Rate...	5 mb/s
Nominal Pulse Width.....	100 ns
Voltage Attenuation.....	30 to 50 db
Nominal Load Impedance.....	50 ohms
Nominal Drive Impedance.....	50 ohms
Signal to Noise Ratio.....	6:1 to 10:1 at up to 5 mb/s
Input Terminal Resistance.....	100 ohms min. at 5 mc/s
Output Terminal Resistance.....	10 ohms to 100 ohms at 5 mc/s
Input Terminal Capacitance.....	600 pf max. at 5 mc/s
Output Terminal Capacitance.....	4000 pf min. at 5 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" to 2" x 1/2" to 6" x 8" x 3/4"

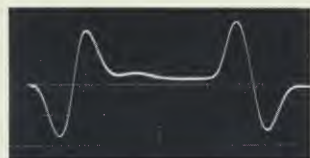


INPUT PULSES



OUTPUT PULSES

SWEEP RATE 100 NS/CM



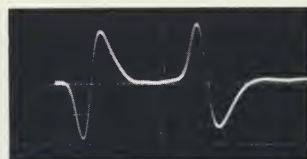
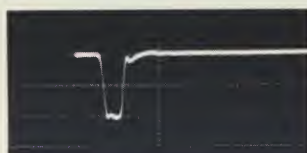
Type QZ-10

Delay Range.....	0.5 μ sec to 325 μ sec
Maximum RZ Bit Rate.....	10 mb/s
Nominal Pulse Width.....	50 ns
Voltage Attenuation.....	60 to 84 db
Nominal Load Impedance.....	50 ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	6:1 to 10:1 at up to 10 mb/s
Input Terminal Resistance.....	4K ohm to 10K ohm at 10 mc/s
Output Terminal Resistance.....	4K ohm to 10K ohm at 10 mc/s
Input Terminal Capacitance.....	40 pf to 125 pf at 10 mc/s
Output Terminal Capacitance.....	40 pf to 125 pf at 10 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" x 1" x 1/2" to 5" x 7" x 3/4"

Note: capacitance and attenuation increase and resistance decreases as delay time increases.

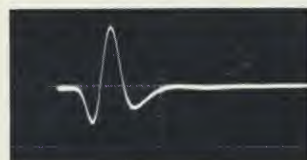


INPUT PULSES



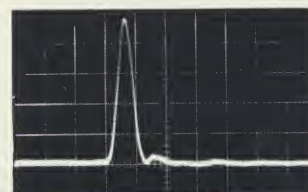
OUTPUT PULSES

SWEEP RATE 50 NS/CM

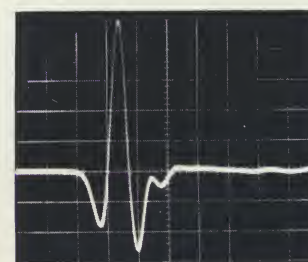
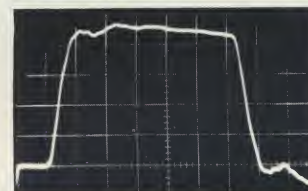


Type QCS-10

Delay Range.....	325 μ sec to 1000 μ sec
Maximum RZ Bit Rate.....	10 mb/s
Nominal Pulse Width.....	50 ns
Voltage Attenuation.....	64 to 84 db
Nominal Load Impedance.....	50 ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	5:1 to 10:1 at up to 10 mb/s
Input Terminal Resistance.....	6K ohm to 10K ohm at 10 mc/s
Output Terminal Resistance.....	2 ohm to 6 ohm at 10 mc/s
Input Terminal Capacitance.....	25 $\pm$ 5 pf at 10 mc/s
Output Terminal Capacitance.....	3000 $\pm$ 1000 pf at 10 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	8" x 8" x 1" to 12" x 15" x 2"

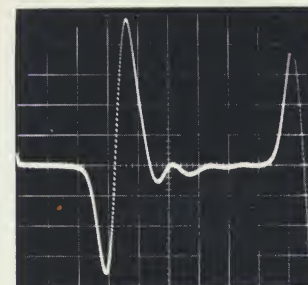


INPUT PULSES



OUTPUT PULSES

SWEEP RATE 50 NS/CM



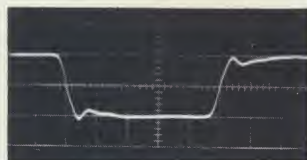
9.1 CORNING GLASS MEMORIES

Standard Bit Rate Series Representative Specifications

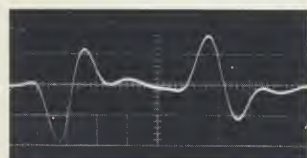
Type QZ-20

Delay Range.....	0.5 μ sec to 175 μ sec
Maximum RZ Bit Rate.....	20 mb/s
Nominal Pulse Width.....	25 ns
Voltage Attenuation.....	60 to 80 db
Nominal Load Impedance.....	50 ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	6:1 to 20:1
Input Terminal Resistance.....	5K ohm to 10K ohm at 20 mc/s
Output Terminal Resistance.....	5K ohm to 10K ohm at 20 mc/s
Input Terminal Capacitance.....	50 pf to 125 pf at 20 mc/s
Output Terminal Capacitance.....	50 pf to 125 pf at 20 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	1" x 1" x 1/2" to 4" x 5" x 3/4"

Note: capacitance and attenuation increase, and resistance decreases as delay time increases.



INPUT PULSES

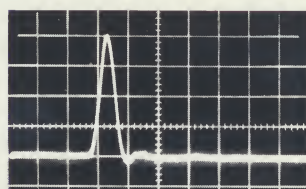


OUTPUT PULSES

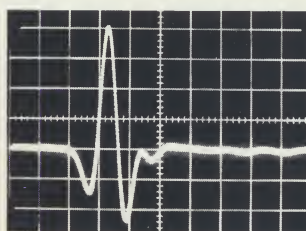
SWEEP RATE 25 NS/CM

Type QS-20

Delay Range.....	175 μ sec to 1000 μ sec
Maximum RZ Bit Rate.....	20 mb/s
Nominal Pulse Width.....	25 ns
Voltage Attenuation.....	60 to 75 db
Nominal Load Impedance.....	50 ohm
Nominal Driving Impedance.....	50 ohm
Signal to Noise Ratio.....	2:1 to 10:1
Input Terminal Resistance.....	10K ohm at 20 mc/s
Output Terminal Resistance.....	10K ohm at 20 mc/s
Input Terminal Capacitance.....	40 to 100 pf at 20 mc/s
Output Terminal Capacitance.....	40 to 100 pf at 20 mc/s
DC Terminal Resistance.....	1 megohm min.
Size.....	5" x 6" x 1" to 12" x 15" x 2"



INPUT PULSE



OUTPUT PULSE

SWEEP RATE 25 NS/CM

9.2 COMPLETED DESIGNS

Following is a list of fully designed Glass Memories with their code numbers. Detailed performance specifications sheets are available upon request.

DELAY TIME CODE NUMBER

Type CZ-2.5

Low Capacitance

18.2 μ sec	853056
27.0 μ sec	853013
44.5 μ sec	853100
45.0 μ sec	853021
50.5 μ sec	853014
100.0 μ sec	853782
110.0 μ sec	853033
166.5 μ sec	853022
167.0 μ sec	853015

High Capacitance

12.5 μ sec	853097
20.25 μ sec	853089
48.5 μ sec	853095
100.0 μ sec	852798

Low Attenuation

10.0 μ sec	853115
----------------	--------

Type CZ-5

25.0 μ sec	853045
100.0 μ sec	853028
199.5 μ sec	853070
200.0 μ sec	853084
240.0 μ sec	853094
332.0 μ sec	853019
399.5 μ sec	853071
400.0 μ sec	853085
405.0 μ sec	853024

Type QZ-10

100.0 μ sec	853036
133.0 μ sec	853098
200.0 μ sec	853005
310.0 μ sec	852776
312.0 μ sec	853053

Type QZ-20

1.0 μ sec	853057
1.25 μ sec	859990
2.0 μ sec	853062
2.1 μ sec	853061
2.8 μ sec	853080
4.3 μ sec	853059
4.5 μ sec	853060
5.6 μ sec	852780
12.4 μ sec	853122
12.5 μ sec	853020
17.3 μ sec	853077
19.9 μ sec	853103
28.0 μ sec	853074
39.7 μ sec	853030
39.8 μ sec	853029
51.6 μ sec	853031
51.7 μ sec	853032
89.7 μ sec	853041
95.8 μ sec	853073
98.2 μ sec	853091
99.5 μ sec	853000
99.6 μ sec	853102
99.8 μ sec	853082
100.0 μ sec	853016
124.5 μ sec	853047
126.7 μ sec	853048
175.0 μ sec	853038

FOR MORE INFORMATION, WRITE TO GLASS MEMORIES
DEPARTMENT, CORNING GLASS WORKS, BRADFORD, PA.

CORNING

ELECTRONICS